Workshop on Mountaintop Mining
Effects on Ground Water

Charleston, West Virginia
May 9, 2000

Workshop Proceedings

Welcome and Introductions

Mr. Mike Robinson, Chief, Program Support Division, Office of Surface Mining, Pittsburgh PA

Mr. Robinson, a member of the EIS Steering Committee, opened the workshop by welcoming the participants and thanking them for their participation and effort to prepare for the meeting. He provided the background of the EIS on Mountaintop Mining with Valley Fills and described how the EIS Steering Committee structured the EIS into Technical Study Areas. He also noted that initially, the potential impact of mountaintop mining and valley fill on ground water was not identified as a major concern and how ground water studies generally take a great deal of time and money to complete. He pointed out that the EIS Steering Committee knew that they had neither the necessary time nor funding to complete a major study on ground water issues and chose to focus their limited resources on the highest priority concerns. However, he noted that the EIS Steering Committee had subsequently concluded that the EIS could not be properly concluded without reviewing the issue of ground water impacts from surface mining operations. He asked for the workshop participants to combine their formidable knowledge and experience on the workshop subject and identify any technical needs that the EIS Steering Committee should consider for additional study or effort to adequately understand the potential impacts of mountaintop mining and valley fills on ground water resources.

Workshop Objectives

Mr. Carey Butler, WPI

Following Mr. Robinson's remarks, Mr. Butler took charge of the workshop and introduced the workshop objectives. These objectives are provided below:

1. Identify potential impacts of mountaintop mining with valley fills on ground water quality and quantity
2. Review existing knowledge and ongoing research that applies to mountaintop mining effects on ground water. Identify knowledge gaps

3. Review and assess the public comments concerning mountaintop mining impacts on ground water received during the EIS Scoping Process
4. Identify potential technical and policy actions in light of workshop findings for further consideration during the EIS process

Mr. Butler also presented his perspective on the key factors for a successful workshop. These included remaining focused on the technical issues and staying clear of value judgments. He expressed the opinion that rendering value judgments are in the domain of government officials and the public and that this group should provide the best technical basis for such judgments. He also asked, in the interest of a timely meeting, that the group to distinguish those technical issues that are vital to good decisions in the EIS process from the many interesting but non-essential issues of ground water science.

Mr. Butler presented a summarized listing of the twelve public comments for use by the workshop participants throughout the day. These are presented below:

Summary of Public Comments Regarding Ground water Issues
(the number of public comments in the summarized group appear in parentheses):

- Unknown changes to the hydrologic cycle (quantity) and water quality of the regional aquifer from filling headwater valleys (4)
- Loss of the aquifer resources due to mining (1)
- Valley fills provide a reliable source of water that enhances downstream productivity (1)
- Blasting shock and chemistry effects aquifer quality (2)
- Blasting shock in undermined areas effects aquifer quantity (2)
- Hazardous materials from mining operations effect ground water quality (2)

Ground-water Aspects of Mountaintop Mining

Mr. Jim Eychaner, U.S. Geological Survey (USGS)

Mr. Eychaner provided the keynote presentation to summarize the effects of mountaintop mining on ground water. He presentation is included as an appendix to this proceedings. In his presentation he outlined the effects in terms of ground water quantity or quality, transient or long-term effects, and immediate or delayed effects. His discussion covered four distinct ground water settings including fracture flow system before mining, intergranular flow system of spoil after mining, fracture flow system after mining and the transient effects of blasting.

He drew largely from the Kanawha-New River Basin Study Unit of the National Water Quality Assessment Program (NAWQA). The Kanawha-New River NAWQA Program studies the 12,223 square miles drained by the Kanawha-New River in the Appalachian Mountains of West Virginia, Virginia, and North Carolina. The Kanawha-New River is one of 59 hydrologic systems being studied by the NAWQA Program. The purpose of

these studies is to describe the status and trends in the quality of ground- and surface-water resources and understand the natural and human factors that affect these resources.

He presented preliminary findings of the Kanawha-New River Study that included 30 wells on the Appalachian Plateau and another 28 wells near reclaimed surface mines. He noted that none of the reclaimed surface mines were near areas that have been subject to mining of the same scale of current mountaintop mining operations. He noted that a report was due to be published soon containing the results of the study and that information about the report could be found at the following URL:

http://wv.usgs.gov/nawqa

Mr. Eychaner also referenced the 1980 study by Berger and Associates that studied blasting effects on ground water from four sites in West Virginia, Pennsylvania, and Ohio. The study noted visible water quality changes immediately after blasting near test wells and that turbidity was the most common citizen complaint in the study. He also noted that turbidity samples collected in the study were only collected after 300 minutes of continuous pumping, which makes the results of limited value when considering residential well applications.

Mr. Eychaner led a workshop discussion on the potential effects of mountaintop mining with valley fills on ground water. During this discussion, Bruce Leavitt commented that researchers have been looking for many years at the hydrology of fill material in the context of acid mine drainage from surface mines. He continued that there should be essentially no difference with a mountaintop mining fill and that these studies should be useful to the EIS conclusion on ground water effects. Mr. Eychaner stated that where the water in the fill discharges from the fill is equivalent to a spring but the residence time in the fill is reduced when compared to the original undisturbed aquifer system.

Jay Hawkins responded to a question by John Hemple regarding seasonal patterns from fill material by suggesting the large storage capacity of a valley fill could reduce peak flow and maintain low-flow above pre-mining discharge levels. Mr. Eychaner remarked that the effect on drought flow is being studied for the EIS. He said that with the addition of fill, small stream low-flow levels are over an order of magnitude greater than before the fill is added and that these data have been provided to the EIS team although he had not seen it published anywhere. He continued that for a flood-flow study, they established stream discharge gauging stations downstream of fill sites and below control sites with no fills. The data were normalized by dividing discharge by drainage area upstream of the gauge site and found that peak discharge is reduced below the mined (and filled) sites.

Mining Operator Requirements and Permit Applications

Dr. Tom Galya, West Virginia Division of Environmental Protection

Dr. Galya presented the requirements for a state surface mining permit that are relevant to ground water effects. The outline of his presentation is provided below and the complete presentation is included as an appendix to this proceedings. Dr. Galya also provided a copy of the complete permit application requirements (MR-4) that are likewise included in the appendix.

SMCRA Permit Application

- Data, Maps, and Analysis is Provided by the Permittee
- Permit Area Geology Data
- Permit Area Hydrology Data
  - Baseline Ground Water
  - Baseline Surface Water
- PHC, HRP, and CHIA Assessments
- SMCRA and NPDES Compliance Monitoring
  - During Mining Ground Water Monitoring Plan
  - During Mining Surface Water Monitoring Plan
- Post-Mining Water Discharge Quality
- Post-Mining Closure
  - Phased Bond Release

NPDES Permit Application

- Ground Water Protection Plan

The areas of the application that require ground water relevant data are Section 1, Geologic Information, of the MR-4 Permit Application with specific information for:

- Drill Hole Data with stratigraphic data and acid-base accounting of seams and overburden
- Geologic Cross Sections
- Hydrogeologic Maps
- Geologic Description of the Permit and Adjacent Area, and
- Anticipated Impacts on Geology and Hydrology of the Permit Area

Section J of MR-4, Hydrologic Information, requires:

- Inventory of Ground-water Users
- Baseline Surface-water Chemistry Data
- Baseline Ground-water Chemistry Data
- Probable Hydrologic Consequences (PHC) of the Proposed Operation, and
- Hydrologic Reclamation Plan (HRP)

The state law requires the Director of the Division of Environmental Protection to prepare a Cumulative Hydrologic Impact Assessment (CHIA) to determine whether the

proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area.

Dr. Galya went on to describe the three phases of bond release after post-mining reclamation that require operators to provide data to validate that the mining operation has met the requirements of the permit application. Dr. Galya also described the Ground water Protection Rules for Coal Mining Operations contained in Title 38 Series 2F of the West Virginia Code. The law requires a Ground water Protection Plan to receive an NPDES Permit for the operation.

The discussion following the presentation several issues were raised. The first centered on the adequacy of guidance and the ability of mine permit applicants to submit sufficient baseline data of consistent quality for the state regulators to perform a consistent review and discern all the possible impacts in the CHIA. The group noted that in some cases, private well owners are unwilling to permit access to their ground water wells to obtain baseline data and Rick Eades suggested proposed a public education component to encourage their participation. Nick Schaer commented that the term "reasonably foreseeable use" is not well defined.

Representatives from Kentucky and Virginia noted that their regulations and experience are similar and suggested that they were also similar in Tennessee. Dave Johnson noted that Kentucky did a field study of 25 permit applications to determine if data in the applications were accurate. He said the results were varied and that they are now doing training of consultants and field personnel. He also noted that a problem in Kentucky is that a person reviewing a permit may not have experience in all the areas to conduct a thorough review of the application. Lynn Haynes said that a review team approach is used in Virginia. Nick Schaer commented that West Virginia processes about 50 permits each year. Bob Evans said that Tennessee uses a similar process but they usually require seasonal data rather than six months, which should better define the complete hydrogeological range.

Public Concerns of Mountaintop Mining on Ground Water

Rick Eades, West Virginia Citizen's Action Group

Mr. Eades talked from a written set of comments that are included in the appendix. He began his presentation by stating the opinion that "citizens are concerned that these (ground water) issues are not addressed, or inadequately addressed, in the largest study ever undertaken to determine environmental impacts from MTR (mountaintop removal) mining. Despite written and verbal requests to EIS overseers, citizens are unaware of meaningful studies to address these concerns." He then listed seven areas of concern that are outlined below. [Facilitator's note: as Mr. Eades written notes were not provided to the workshop participants during the meeting, it is not clear that all the concerns detailed in his notes were given adequate treatment during the workshop.]

- Valley fills (Insufficient effort to study the effects on ground water with monitoring wells during the EIS)
- Water supply wells proximal to blasting
- Permanent ground water storage loss in interburden/coal units
- Ground water loss or impacts below the lower-most bench (up to 600+ feet removed in some areas
- Guidance for determining the point of origin of intermittent streams (versus ephemeral)
- Ground water chemistry
- The basis hydrogeologic regime represents a high degree of complexity

Mr. Eades expressed the concern that citizen's are questioning the lack of commitment of resources, for example money for monitoring wells, to gain direct measurement to assess these potential environmental impacts. He continued by stating the use of indirect (anecdotal) evidence to characterize hydrogeologic impacts has the potential to miss real long-term effects of mountaintop mining. He concluded by stating that the citizen's he represents have a very low degree of confidence in the EIS to adequately characterize ground water impacts from mountaintop mining and would like to have as many resources devoted to ground water monitoring as have been allocated to study economic impacts.

In the discussion that followed, Bill Raney asked "what is the difference between mining now and mining in the 1980's." Mr. Eades replied that mined out areas are now in much thicker strata and cover larger areas, sequencing of blasts has evolved, and there is continual subsidence. John Hemple added the Berger and Associates study (on blasting near wells) is a start, but today's blasting areas are larger, and changes in blasting threaten to open previously sediment-blocked fractures.

There was a general discussion of drilling wells through spoil material. David Wunsch noted that he has done a lot of study in this area and creating stable deep wells in spoil material is very difficult. Rodney Woods expressed the opinion that it must be difficult to find a contractor who will take the risk of drilling such a well with the high potential for losing drill bits in deep spoil.

Effect of Mountaintop Mining Induced Fracture on Aquifer Hydrology

Mark Kozar, USGS

Mr. Kozar gave a presentation entitled, "Age of Ground water in the Kanawha-New and Allegheny-Monongahela River Basins." In this presentation, he gave the results of chlorofluorcarbon (CFC) dating of water samples taken from wells in these regions to determine water age. CFC dating is a result of the relatively recent appearance of CFC in the atmosphere and, therefore, the know time (1940's) in which this tracer was introduced into ground water recharge zones. He noted that the age of water in hilltop wells of the Kanawha-New River Basin averages about 19 years of age while water in

hillside and valley wells averages 29 and 42 years, respectively. He went on to note that the younger age in of ground water in mined areas may indicate increased ground water flow velocities due to enhance permeability. He suggested that this factor should be reflected in ground water models and regulations designed to protect ground water in fractured bedrock aquifers of the region.

The group discussion that followed centered on whether or not longer ground water travel times would be realized. John Hemple asked if Mr. Kozar's conclusion means that removing the recharge area might lengthen the recharge time. David Wunsch stated that fractures are dynamic and many quickly become filled with mud. Bruce Leavitt commented that not all material is placed in the valley; much of the material is placed back on the bench in back stacks. Jay Hawkins mentioned that there are studies on the issue of recharge in mined areas that were conducted in Ohio.

Blasting in Mountaintop Mining

Jay Hawkins, Office of Surface Mining

Mr. Hawkins presented a report entitled, "Impacts of Blasting on Domestic Water Wells" that drew from both his personal research and the research of others. His complete presentation is included in the Appendix. Mr. Hawkins researched the effects of blasting from 1994 to 1995 when he worked for the Bureau of Mines. He reported the preliminary results of his study of a study in Clearfield County, Pennsylvania with similar topographic characteristics to a mountaintop mining operation in southern West Virginia but on a smaller scale. The study included instrumented logging of several nested wells to examine the effects of blasting on water levels and aquifer characteristics both in the horizon of the coal seam being mined and the next lower coal seam that represented the first yielding unit below the water-table aquifer.

According to Mr. Hawkins, the blasting ranged from 50 to 100 holes with approximately 60 feet of overburden initially at a range of about 900 feet from the wells. He reported that there was no observable ground-water fluctuations that could be attributed to the blasting with monitoring covering up to 20 minutes after the blasts. Mr. Hawkins also reported that in this study, there were no observable changes in the aquifer characteristics identified by the slug tests and constant-discharge well tests that were conducted before and after the blasting. He noted that eventually, pumping of the mine pit and encroachment of the highwall toward the wells dewatered the water-table aquifer.

Mr. Hawkins also discussed three other published studies how blasting affects domestic water wells including D.A. Roberson (1988), D.E. Siskind and J.W. Kopp (1987), and J.A. Kipp and J.S. Dinger (1991). His report on these studies is detailed in his presentation.

He concluded that depending on well construction, lithologic units encountered, and proximity to the blasting, some of the larger blasting shots could act as a catalyst for

some well sloughing or collapse. However, he added, the well would have to be inherently weak to begin with and that smaller blasting shots are not likely to cause these effects. He also concluded that minor water fluctuations from blasting may cause short term turbidity increases but should not pose long-term water quality problems. He did allow that the issue of residual nitrates from blasting as a source of ground water contamination has not been adequately addressed and may need further study.

In the discussion that followed, John Hemple agreed that larger shots could trigger a well to slough and cited an anecdote of a well that became contaminated with fecal coliform after nearby blasting. Dave Johnson commented that, in his experience, most complaints are from people in valleys, while mining is occurring nearby at higher elevations. Mr. Hawkins listed four relevant questions regarding blasting as (1) the nitrates issue, (2) pre-blast well testing of yield, (3) water quality testing and a number of samples (6-12) taken over a year, and (4) regulated scaled distances and peak-particle velocities. He also commented that blasting should be avoided on days with temperature inversions as this would reduce the public perception of damage by eliminating the shock wave reflected off the inversion. Mike Robinson commented that the Office of Surface Mining does have a complaint group and is considering funding a study. Jim Eychaner stated that they normally see small nitrate values in domestic wells.

Ground-water Flow through Unconsolidated Materials

David Wunsch, Kentucky Geological Survey

Mr. Wunsch reported on a comprehensive study of ground water flow through unconsolidated materials that was conducted at the Star Fire Tract in eastern Kentucky. He stated that there is a higher conductivity for ground water in coal seams and cited a recent dissertation, which is being published by the Kentucky Geological Survey. He discussed a well design for use in fill material that has an increased probability of remaining intact as the fill material shifts and settle. He noted the following issues that should be considered, (1) comparing bench-scale studies with field observations, (2) spoil settlement, and (3) establishing GIS databases.

The complete report on the Star Fire Tract is available from the Kentucky Geological Survey using the hyperlink in the citation below:

Report of Investigations 6 (series 11), **Design, Construction, and Monitoring of the Ground-Water Resources of a Large Mine Spoil Area: Star Fire Tract, Eastern Kentucky,** by David R. Wunsch, James S. Dinger, and Page B. Taylor, 1992, 16 p.

Ground-water Chemistry Effects and Ground-water Monitoring

Bob Evans, Office of Surface Mining

Mr. Evans prepared presentations with great detail on each of these subjects but was allowed only ten minutes to quickly summarize his points so the group could move on to summarizing ground water issues raised during the workshop and developing recommendations.

Mr. Evans highlighted several actions that could be taken to reduce the uncertainty of operators and regulators on ground water issues in mining permits. These are summarized below:

- Conduct field studies of existing mining operations to relate site geochemistry to post-mining water quality
- Better establish the ground water flow paths through mine backfills and valley fills
- Enhance the experiential knowledge base of reviewers and permit preparers through standardization of testing methods, databases, field studies, etc.
- Establish post-mining water quality from backfills and valley fills to validate PHC predictions
- Develop electronic data submission/storage requirements for submission of geologic and hydrologic data.

Mr. Evans pointed out the crosswalk he prepared between federal regulations and the regulations of West Virginia, Virginia, and Kentucky for Ground water Baseline Requirements and Ground water Performance Monitoring Plans.

The workshop participants expressed their appreciation for the obvious hard work Mr. Evans had put into his presentations and asked that both presentations be included in the workshop proceedings. These presentations are included in the appendix.

Facilitated Open Discussion

Mr. Butler facilitated an open discussion of the group toward a set of recommendations regarding additional scientific study or regulatory enhancements necessary to identify and protect against the potential detrimental effects of mountaintop mining on ground water resources. He organized the discussion around five major technical areas that had been addressed during the day. They were:

1) Baseline Hydrology Assessment
2) Fracture Hydrology (long-term effects)
3) Blasting (short-term or transient effects)
4) Fill Hydrology
5) Aquifer Resource Issues

Mr. Butler then added bulleted sub-items that were discussed during the day and asked the group to add to or modify the bulleted lists until they were satisfied. Then for each technical area the group was asked to identify thoughts or suggestions that had been heard during the day that would contribute to either improved science or enhanced regulations regarding mountaintop mining and the potential effects on ground water. Finally, the group was asked to synthesize from those thoughts and ideas a specific list of essential recommendations for additional scientific study or regulatory modifications to address the uncertainties of mountaintop mining effects on ground water.

Under science issues, the group was asked to consider whether there was sufficient scientific knowledge to be sufficiently predictive regarding potential effects of mountaintop mining on ground water. Under regulatory issues, the group was asked to consider if existing permitting regulations required sufficient data of the right type and quality to render an adequate decision regarding the potential effects of mountaintop mining on ground water. Under each topic below, the area issues are listed under the main technical area heading followed by comments and recommendations (italicized) to address key areas of uncertainty in both Science and Regulation.

1) Baseline Hydrology Assessment

- Adequacy of Requirements
- Adequacy of Application Information
- Adequacy of Review

Science no comments or recommendations

Regulation

Standardization of Permit Review	*Electronic Data Submission*
Technical Audits- QA/QC	
Depth of well water, seasonality	*Policy for measured well yield determination*
Variability among states	
Sampling plans	

There was substantial discussion among the workshop participants on the value and meaning of well yield testing required by permit applicants. The group considered several issues including how many wells are needed, which is dependent on the methodology of geostatistics that is considered appropriate for the circumstances. The group also considered if it was adequate to simply measure water levels at a single moment or if more data were necessary to account for daily and seasonal patterns of consumption and recharge. Finally, the group discussed whether or not the state should require the applicant to drill wells as part of pre-application monitoring.

David Wunsch commented that we want the application and decision to be based on sound science and not just “feel good” application of the regulations. He noted that

Kentucky is developing a database of wells that are useful for monitoring. Tom Galya noted that decisions regarding how many wells to use and where they are located is determined at the pre-permit meeting. Dave Vande Linde stated that West Virginia is moving to a tiered review process where initial data is reviewed and decisions are made about additional monitoring or adding wells. Mr. Vande Linde also noted that West Virginia is implementing a random technical review of permits for quality assurance and quality control purposes.

The group endorsed two recommendations in the interest of improving the baseline hydrology assessment during the permitting process. First, the group recommended moving to an electronic data submission process as recommended by Bob Evans during his presentation. This will improve the standardization of permit application review and quality assurance audits. Second, the group recommended establishing a regulatory policy for measured flow in terms of obtaining accurate discharge and stream yield measurements.

Second, the group recommended establishing a regulatory policy for measured flow. Discharge reported for either pumped wells or streams typically has been an estimate with no supporting documentation, in contrast to chemical analyses that are supported by detailed QA plans. The group recommended that all flows reported to WV DEP be measured using an identified method appropriate to the situation.

2) Fracture Hydrology (long-term)

- Aquifer Dewatering
- Recharge

Science

USGS Work
Ohio Study
KY thesis

Improved Conceptual Models

Regulation no comments or recommendations

The group recommended that the conceptual model for flow through fractured bedrock be improved by considering the greater age of ground water as presented by Mark Kozar earlier in the workshop. Jim Eychaner further commented that we need to improve the science, through observations that can lead to improved models, before we propose any changes to the regulations.

3) Blasting (ST/Transient)

- Well Integrity
- Water Quality

Science

Berger Study	*Nitrates*
Montana work	*New Study in PA*
	Turbidity/Total Suspended Solids

Regulation

Monitoring Wells in Valleys
Max Peak Particle velocity
Pre-blasting survey (WV Law)

Under the topic of science, the group addressed the question of whether the Berger and Associates 1980 study is still adequate considering the increased magnitude of blasting operations in mountaintop mining. Jay Hawkins commented that vertical shock is not necessarily of concern because the mine operator tries not to break the coal bed when blasting. Mr. Hawkins also commented that he does not think nitrate contamination of ground water from blasting operations is a problem. However, he continued, this potential impact has not been well studied.

Tom Galya stated that analysis for Total Suspended Solids (TSS) is not currently required. Nick Schaer added that many labs perform the TSS protocol as part of other laboratory tests. Dr. Galya proposed that TSS be made part of the standardized suite of analyses and reports required with permit applications.

Jay Hawkins commented that a proper pre-blasting survey could help define the potential effects of a blasting operation and limit potential liability for all parties. Rick Eades stated that it is part of the law in West Virginia but, in actuality, these studies are very limited in scope.

The group endorsed recommendations for study on the issue of nitrates from blasting as a potential ground water contamination source, support for the potential new study on blasting effects at a mining site in Pennsylvania identified by Jay Hawkins, and adding TSS to the standard list of analyses for ground water samples. The group also endorsed including monitoring wells in valleys adjacent to mountaintop mining sites in the monitoring plan, review limiting maximum peak-particle velocity of blasting operations, and raising the regulatory rigor of pre-blasting surveys.

4) Fill Hydrology

- Recharge
- Well Dewatering
- Storage Capacity (seasonal)
- Equilibrium Chemistry (water quality)
- Monitoring

Science

Star Fire Tract	*Conclude Star Fire Tract residual studies*
ODEX drilling	
USGS work at monitored sites	E*nhancements to USGS work (chemistry)*

Regulation no comments or recommendations

The discussion under this topic considered the potential for significant differences between fills constructed from sandstone and shale overburden. Jim Eychaner suggested this was an area for additional study and that the improvements in science would be reflected in better permit reviews. The group identified two immediate opportunities for improving the science of fill hydrology. The first is to conclude many of the unfinished topical studies at the Star Fire Tract and the second is to enhance the current USGS study by increasing the chemical analyses that are being conducted.

5) Aquifer Resource

- Relative productivity of perched aquifers and fills
- Effect on regional ground water aquifer from filling headwater streams

Science

Ballard Site	*Recharge Mass Balance*

Regulation no comments or recommendations

The group identified the need for development of water budget (mass balance) estimates for both pre- and post-mining conditions. Rick Eades stated that the Ballard site study will include the performance of a recharge mass balance. Jay Hawkins commented that this information is generally well known but the studies have not been collected and integrated.

Reuben Gillispie (reubengillispie@wvdhhr.org) noted that the state does not specify a list of significant aquifers. Instead, a vague definition is applied on a case-by-case basis. Bob Evans said that if the aquifer is designated as a sole-source aquifer, then EPA will not allow any activity that threatens the aquifer. The CHIA, he said, requires you to determine if there will be damage to the aquifer off-site. Despite this discussion, the group did not endorse any recommendations regarding naming significant aquifers or the CHIA.

Workshop Conclusion

The workshop was concluded following the open discussion and development of recommendations. Recommendations will be forwarded to the EIS Steering Committee for consideration.

Attachments:

Workshop Agenda

Meeting Participants

Public Comments

Presentations:

Eychaner

Galya

Eades

Kozar

Hawkins

Wunsch

Evans (2) Ground Water Monitoring

Ground Water Geochemistry Effects